State of New York   )
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AFFIDAVIT

On this day, Suzanne F. Gagliardi personally appeared before me and after being duly sworn, deposes and states:

1. That she is accredited by the American Translators Association as a translator of German to English and is employed as such by Kenyon & Kenyon (One Broadway, New York, New York 10004);

2. That she has carefully made the attached English language translation from the original document,

German Patent Application no. DE 100 18 556.8 filed on 4/14/2000 at the German Patent Office entitled

"Verfahren zur Regelung der Geschwindigkeit eines Fahrzeugs"
[Method for Controlling the Speed of a Vehicle],

written in German; and

3. That the attached translation is an accurate English version of such original to the best of her knowledge and belief.

Suzanne J. Gagliardi
SUZANNE F. GAGLIARDI

Subscribed and Sworn to before me this 27th   day of
August   , 2003.

Diane M. Skripko
Notary Public

METHOD FOR CONTROLLING THE SPEED OF A VEHICLE

Background Information

The present invention is directed to a method for controlling the speed of a vehicle, particularly under consideration of

5   vehicles driving ahead, in accordance with the definition of the species in the main claim.

From German laid open print DE 42 42 700 A1, it is known to mount a radar or infrared sensor on a vehicle to detect

10   vehicles driving ahead. This radar sensor can be, for example, a module of a vehicle comfort and convenience system ACC (adaptive cruise control), in which information pertaining to the distance and the relative speed of the vehicle with respect to other vehicles and information on road conditions

15   are continually processed.

The basic functions of the above described system relate to the control of the vehicle speed, either to a setpoint value, here the desired speed, or to the speed of a vehicle driving

20   ahead, in the case that the latter is traveling at a slower speed than the desired speed and is within the sensing range of the radar sensor. As mentioned above, this sensor can be, for example, a component of a microwave radar or of an infrared lidar and, to that end, it measures the distance, the

25   relative speed, and the angle of objects, particularly of vehicles driving ahead within the sensing range.

From German Patent DE 197 22 947 C1, a method is known, where, in addition to measuring the quantities described above, the

30   ACC system also includes the future travel-course progression of the vehicle, along with the ACC system, in the control in

order to determine the future travel corridor. For this, the future travel-course range of at least one vehicle driving ahead is determined, and a lateral offset is then ascertained for all detected vehicles. Given steady-state curvature

5   conditions of the roadway, i.e., in a linear portion or in the region of constant curvature of a curve, the future travel corridor is also able to be easily determined using the known method, with the aid of a well-adjusted yaw-rate or rotation-rate signal.

10

From the yaw rate of the ACC vehicle, the curvature of the roadway and, therefore, also the travel-course offset of a vehicle traveling ahead can be determined here, using generally known method steps. If this travel-course offset is

15   smaller in terms of absolute value than a predefined width of the travel corridor, then one can infer that the vehicle traveling ahead is located in the travel corridor of the ACC vehicle. When working with changing conditions, particularly in the beginning curve region, however, one is normally no

20   longer able to correctly determine the association with the travel corridor, so that it can happen that a vehicle driving ahead in the right, adjacent lane, near the beginning of a left curve, is incorrectly attributed to the travel corridor. This leads to faulty control reactions, the cause here being

25   the mistaken curvature prediction, since the ascertained curvature is always specific to the current instant and, therefore, the reaction to a change in curvature is always too late.

30

Summary of the Invention

A method for controlling the speed of a vehicle of the type mentioned at the outset, where, in the vehicle to be controlled, the yaw rate or rotation rate is measured, in particular to determine the curvature of the vehicle's own travel trajectory, and where, using a proximity sensor or position sensor, at least one vehicle traveling ahead or at least some other object within a sensor's sensing range is detected with regard to an offset from the travel course of the vehicle to be controlled, is advantageously further refined in accordance with the present invention by the characterizing features of the main claim.

As already mentioned at the outset, curvature k of the roadway may be calculated in a simple manner from the measured yaw rate of the ACC vehicle to be controlled using generally known method steps in that the yaw rate is divided by the speed, and, using that, the travel-course offset yc of a vehicle traveling ahead may also be determined. Specifically, travel-course offset yc may by determined by the following formula:

$$yc = yv - k*d^2/2,$$

quantity yv being the measured lateral offset, without allowing for curvature k, and d being the distance between the vehicle to be controlled and the measured vehicle driving ahead.

If this travel-course offset yc is smaller in terms of absolute value than a predefined width y_{lane}, then one may infer that the object or the vehicle is located in the travel corridor of the ACC vehicle, y_{lane} corresponding approximately to one half of a lane width.

In accordance with the present invention, travel-course offset yc of a vehicle driving ahead, determined in preset measuring cycles, is delayed by a predefined time lag, and using the instantaneous curvature k of the travel trajectory of the

5   vehicle to be controlled, a historical travel-course offset yc_{hist} is ascertained. In this context, the delay may advantageously be selected such that historical travel-course offset yc_{hist} is determined after approximately half of the distance between the vehicle to be controlled and the measured

10   vehicle.

Therefore, alternatively to the generally known method of looking ahead using video-based lane detection or navigational systems, the method according to the present invention for

15   controlling an ACC vehicle permits, in a simple manner, a relatively fast and simple-to-implement historical comparison between the position and travel trajectory of the vehicles. Instead of a costly, continuous transformation of the measured data, the present invention provides, in simplified fashion,

20   for measured lateral offset yv to be delayed by about time span t_{hist}, commensurate with half of the time span between the vehicles.

From this so delayed value yv_{hist}, as above, using active

25   curvature k, the so-called historical travel-course offset yc_{hist} is now determined in accordance with the relation:

$$yc_{hist} = yv_{hist} - k * d_{hist}^2 / 2$$

30   d_{hist} being generated or estimated, likewise on the basis of a delay, as the historical distance between the vehicle to be controlled and the measured vehicle. For example, in accordance with the relation

35   $$d_{hist} = d_{active} - vr * t_{hist}.$$

Thus, distance d_{hist} takes into consideration the change in distance in response to speed differences. In illustrative terms, the mechanism functions as follows: the curvature determination is made approximately at the middle of the

5 distance between the ACC vehicle and the measured object, although delayed by t_{hist}. Even when working with changing curvatures, the average curvature is a good estimation here and allows a quite precise determination of travel-course offset.

10

To avoid unwanted transient effects in those cases where the object had not yet been measured for the length of time span thist and, consequently, no historical lateral offsets exist, it is advantageous when a dynamically increasing delay time

15 $t_{hist/dyn}$ takes the place of time t_{hist}, the time span until maximum value t_{hist} is reached being supplemented by the dynamic component that increases with the duration of observation. Until this maximum value is reached, the quality of the thus calculable yc_{hist} is somewhat lower, but this value is always

20 ready as a transitional value.

In addition, a filtering is advantageous to compensate for short-term curvature fluctuations caused by steering motion or signal noise. Since this filtering likewise delays the active

25 signal by t_{filter}, the delay in the yv values must likewise last longer by approximately this value. The delay may be advantageously further modified, for example, by filter times of active curvature signal k. In this connection, the instantaneous value of curvature k of the travel trajectory of

30 the vehicle to be controlled, at any one time, is delayed by a preset value for averaging purposes, this delay being considered as well in the determination of historical travel-course offset yc_{hist}.

35 Although the delay times are known, so that t_{hist} is generated

from the sum of half of the time gap and the filter time, such modifications of time span t_{hist} may be useful in order to achieve a functional optimum by way of a total adjustment. This applies, in particular, when the quantities are not only filtered by a delay element, but are also averaged via low-pass-type filters. The latter is also used here for reducing measuring fluctuations. Delay element and averaging filter may be combined in simple fashion, for example, by using filters having a most constant possible group delay, e.g., Bessel filters or series-connected filters having a critical attenuation.

In summary, the method of the present invention enables historical travel-course offsets to be generated in simple fashion, in particular by combining averaging and delay, without necessitating a costly storing of lane data or transformation of such stored data. A rapid result is achieved, since one only has to wait for about half of the time gap up until the result.

To obtain a still further improved method for predicting the path of the vehicle to be controlled, it is also possible for a number of further detection devices for determining the travel-course offsets of objects traveling ahead to be present in the vehicle to be controlled. All results of these detection devices may then be analyzed and weighted. The analysis and weighting may preferably be carried out using a video camera, a preferably satellite-supported navigational system, a set-up for analyzing fixed destinations, or a set-up for determining a collective yaw or rotation rate of the objects driving ahead.

These and other features of preferred embodiments of the invention are derived from the claims, as well as from the specification and the drawings, it being possible for the

individual features to be realized individually or multiply in the form of subcombinations in the specific embodiment of the present invention and in other areas, and to constitute advantageous and patentable embodiments, for which protection

5 is claimed here.

Brief Description of the Drawing

The method according to the present invention for controlling

10 the speed of a vehicle, under consideration of objects driving ahead, is elucidated on the basis of the drawing, whose figures show:

Figure 1   a sketch of a curved roadway path, including a

15   vehicle whose speed is to be controlled, and further objects;

Figure 2   a sketch of a curved roadway path, including a vehicle whose speed is to be controlled, and further

20   objects at various points in time;

Figure 3   a diagram of the output signal of a delay-producing filter;

25 Figure 4   an overview diagram of a lane probability with respect to objects located in a travel corridor;

Figure 5   a diagram for assessing the various lane probabilities; and

30
Figure 6   a block diagram relating to the analysis and weighting of various detection methods used to detect objects moving ahead.

35

Detailed Description

Figure 1 shows an ACC vehicle 1 to be controlled, which is
located on a roadway 2 having a plurality of lanes. Vehicle 1
5   has, for example, a radar sensor 3 having a radar detection
range 4; other detection set-ups are also mountable on vehicle
1, such as video or navigational devices, which may be used to
detect roadway 2 or the area surrounding the roadway. Situated
on roadway 2 as an object driving ahead is a vehicle 5, in
10   reality, a plurality of such objects being present at various
distances and at different speeds.

The ACC system in vehicle 1 includes a control system (not
explained in further detail here) for influencing speed, and a
15   plurality of sensors, such as a yaw-rate or rotation-rate
sensor, a steering-angle sensor, wheel-speed sensors, or a
transversal-acceleration sensor. A dot-dash line 6 represents
the future desired travel-course progression, i.e., the travel
trajectory of vehicle 1, and the two lines 7 show the future
20   travel-course range or travel corridor. A line segment 9
indicates the lateral or travel-course offset of vehicle 5
driving ahead with respect to the travel course of vehicle 1.

The assumption is made in the following, with reference to
25   Figures 2 and 3, that, to correct the curvature of travel
trajectory 6 of vehicle 1 in light of a curvature to be
expected of roadway 2, a historical travel-course offset or
lateral offset is used in the calculation.

30   In accordance with the exemplary embodiment illustrated in the
drawing, travel-course offset yc of a vehicle 8 driving ahead
is delayed by a predefined time span, and using the then
active curvature k, a historical travel-course offset ychist
is determined at instants t_1, t_2, and t_3 of travel trajectory
35   6. In this context, the delay may advantageously be selected

such that historical travel-course offset yc_{hist} is defined approximately at half of the distance between vehicle 1 to be controlled and vehicle 5 to be measured.

5   From this thus delayed value yv_{hist}, so-called historical travel-course offset yc_{hist} is now determined, as above, using active curvature k, according to the relation

$$yc_{hist} = yv_{hist} - k*d_{hist}^2/2.$$

10

Figure 3 shows a diagram of the output signal of a delay-producing filter. The time is shown in seconds on the horizontal axis, and the characteristic curve of an output signal is shown on the vertical without units/theoretically.
15   The illustrated, exemplary characteristic curve shows a maximum of the output signal in the region of approx. 0.8 seconds. This maximum must be appropriately adapted to the desired delay.

20   The following describes a method for performing the previously described calculation, with the involvement of historical travel-course offset yc_{hist} for predicting a travel course. The selected abbreviations represent the common short forms of the corresponding physical quantities used for inputting into a
25   data-processing system. For the sake of simplicity, the trajectory is assumed in this case to be a piece-wise constant parabola. The parabola curvature is defined approximately in the middle of the section between object 5 and vehicle 1 (compare Figure 2). Since the now single trajectory
30   coefficient is defined already when the middle is reached, a delay in the object lateral offsets yv is also only necessary up to the middle. The time delay is achieved, for example, by a triply cascaded low-pass filter (not shown here) having a dynamic time constant Tauy for improving the transient
35   response. Here, the following relations apply:

$Tauy(t_j) = MIN(TauyMax(t_j), TauyMax(t_{j-1}) + T_{cycle});$

in the case that a valid measured value exists for the object, otherwise it follows that

$Tauy(t_j) = MAX(0, TauyMax(t_{j-1}) - T_{cycle}/2)$

where

$Tauy(t_j)MAX = fTauyd * (d(t_j)/vRef(t_j)) + fTauyKap * TauKap.$

The filtering using the three low-pass stages yields a total group delay of $3Tauy(t_j)$. Thus, in three measuring cycles, one obtains the following lateral offsets:

$yvl(t_j) = (T_{cycle}/Tauy(t_j) * (yv(t_j) - yvl(t_{j-1})),$

$yv2(t_j) = (T_{cycle}/Tauy(t_j) * (yvl(t_j) - yv2(t_{j-1})),$

$yv3(tj) = (T_{cycle}/Tauy(tj) * (yv2(tj) - yv3(tj- 1)).$

From output value $yv3(t_j)$ of the filter, with the aid of trajectory curvature $k_{Traj}(tj)$ (previously the value = k), the historical lateral offset to the middle of the course may be calculated as follows:

$ycHist(t_j) = yv3(t_j) - k_{Traj} * (d(t_j) - vr(t_j) * 3TauDy(t_j))^2/2.$

In this case, $vr(t_j) * 3Tauy(t_j)$ corrects the active distance to historical reference point $t_j - 3Tauy(t_j)$.

As a further characteristic quantity for the quality of the historical lateral offset, quantity ycHistQ is used; it is calculated from angular quality Qalpha (e.g. = 1) and from the observation duration for the calculation of the historical

lateral offset:

$$ycHistQ(tj) = MIN(1, ycHistQ(t_{j-1}) + Qalpha * T_{cycle}/TauHist(t_j))$$

5 respectively,

$$TauHist(tj) = fTauHist * (d(t_j)/ v_{Ref}(tj)),$$

in the case that an object was measured, and a valid
10 travel-course offset is at hand. Quantity fTauHist stands here
for the fractional portion of the time gap, starting from
which a steady-state performance is assumed. Otherwise, it
holds that:

15 $$ycHistQ(t_j) = MIN(0, ycHistQ(t_{j-1}) - Tcycle/TauHist(t_j)).$$

Since the historical lateral offset is not available in
sufficient quality until a relatively long waiting time has
elapsed, on the basis of active lateral offset yv and the
20 active travel-course curvature, an active travel-course offset
yc_{Act} is determined, which is able to provide a lateral
travel-course offset as soon as there is a first measurement
of an object:

25 $$yc_{Act} = yv - yv_{Course} = Yv - d^2 * k_{Course}/2.$$

Figure 4 is a graphic representation illustrating the lane
probability of the measured objects, active lane probability
spwAct and historical lane probability spwHist following in
30 parallel, in the same manner, for active lateral offset yc_{Act}
and for historical lateral offset yc_{Hist}.

As is apparent from Figure 4, the basis of the previously
mentioned lane probability determination is a surface having
35 constant width L. Within this surface, a positive lane

probability is assigned, while outside of it, it becomes negative. The highest probability is assigned when yc is situated within the inner surface.

5   Similarly to the generally known fuzzy logic, the transitional region may be selected to be fuzzy, making it possible to determine a lane probability of -1 to + 1. The width of transitional region spw advantageously increases in response to a large distance.

10

A mixture of the described lane probabilities is shown in a diagram according to Figure 5. The two lane probabilities spwAct and spwHist are weighted as a function of the quality of historical lateral offset ycHistQ in the time Tauy and

15   mixed to form a new value spw. Weighting factors f_{Act} and $f_{act}+f_{Hist}$ from the diagram according to Figure 5 are generated as follows. f_{Hist} for ycHistQ is large in the case that the observation time corresponds approximately to TauyMax. f_{Act} may be constant or otherwise determined.

20

If, in this case, yc_{Act} and yc_{Hist} point to different travel lanes, then the values compensate for one another in accordance with the weightings f_{Act} and f_{Hist}. If, on the other hand, they are on the same lane, then they reinforce one

25   another up to the maximum value $f_{Act} +f_{Hist}$.

Figure 6 shows a block diagram 40, which indicates various possibilities for detecting and evaluating object in travel-course progression k of an ACC vehicle, which may also

30   be used in different combinations, individually or together. In left branch 41, a calculation is shown of a future travel-course progression by adding the vehicle's own trajectory from the vehicle's own yaw rate, to a collective yaw rate in a block 42. In a block 43, by consulting the

35   active object data, a decision may now be made as to whether a

detected vehicle is located in the vehicle's own calculated travel corridor and, therefore, comes under consideration as an object to which the vehicle's own speed should be adapted. If this is answered in the affirmative, the actual control may be carried out in a control system 44.

For this, in a parallel branch 45, it is intended for a video system 46 to be present, which likewise is able to define the vehicle's own travel corridor and detect an object driving ahead as a control object.

In a further branch 47, a navigational system 48 is provided, which, with knowledge of the vehicle's own position and, under consideration of existing map material, is able to effect the same control mechanisms as previously described.

In a further branch 49, in a module 50, a travel course prediction may be made for ACC vehicle 1, which, in the calculation, considers the previously described, historical, lateral offset between ACC vehicle 1 and a detected object (vehicle 5, 8).

In another parallel branch 51, in a module 52, a travel course determination may also be made using a travel-course offset ascertained by interpreting the position of fixed destinations, for example at the edge of the roadway.

In actual control system 44, by analyzing the results from the calculations of individual branches 41, 45, 47, 49, and 51, a final decision may now be made with respect to the selection of the vehicle driving ahead, if indicated, including a weighting of the individual results, to which the ACC vehicle adapts its speed.

What is claimed is:

1.   A method for controlling the speed of a vehicle (1),
where,

- in the vehicle to be controlled, the yaw rate or rotation
  rate is measured, in particular to determine the
  curvature (k) of the vehicle's own travel trajectory, and
  where,

- using a proximity sensor or position sensor (6), at least
  one vehicle (8) traveling ahead or at least some other
  object within a sensor's sensing range (7) is detected,
  particularly with regard to an offset from the travel
  course of the vehicle to be controlled,
  wherein

- the travel-course offset (yv) of a vehicle (5,8) driving
  ahead, determined in preset measuring cycles, is delayed
  by a predefined time lag (t_{hist}), and using the then active
  curvature (k) of the travel trajectory, a historical
  travel-course offset (yc_{hist}) is ascertained.

2. The method as recited in Claim 1,
wherein the delay is selected such that the historical
travel-course offset (yc_{hist}) is determined after approximately
half of the distance between the vehicle (1) to be controlled
and the measured vehicle (5,8).

3. The method as recited in Claim 1 or 2,
wherein the historical travel-course offset (yc_{hist}) is
determined in accordance with the relation $yc_{hist} = yv_{hist} - k*d_{hist}^2/2$,
d_{hist} likewise being generated or estimated as the historical
distance between the vehicle (1) to be controlled and the
measured vehicle (5,8) on the basis of a delay.

4. The method as recited in Claim 3,
wherein the historical distance (d_{hist}) is estimated according
to the relation $d_{hist} = d_{active} - vr*t_{hist}$.

5. The method as recited in Claim 2 or 3,
wherein the time span until the maximum value (t_{hist}) is reached
is supplemented by the component that increases with the
duration of observation, to form ($t_{hist/dyn}$).

6. The method as recited in one of the preceding claims,
wherein the instantaneous value of curvature (k) of the travel
trajectory of the vehicle (1) to be controlled, at any one
time, is delayed by a preset value, this delay being
considered as well in the determination of the historical
travel-course offset (yc_{hist}).

7. The method as recited in one of the preceding claims,
wherein for the active (YC_{Act}) and the historical travel-course
offset (yc_{hist}), a lane probability (spwAct, spwHist) of the
measured vehicle (5,8) is determined for the own lane and/or
for the adjacent lanes (spwL, spwR) of the vehicle (1) to be
determined.

8. The method as recited in Claim 7,
wherein the two lane probabilities (spwAct,spwHist) are mixed
as a function of the quality of the historical lateral or
travel-course offset (yc_{hist}) to form a new value (spw).

9. The method as recited in one of the preceding claims,
wherein in the vehicle (1) to be controlled, a number of
further detection devices (41,45,47,49,51) are provided for
measuring the position of the objects (5) driving ahead, and
to select an object (5,8) driving ahead as the vehicle to
which the speed of the vehicle to be controlled should be
adapted, all results from these detection devices
(41,45,47,49,51) are evaluated and weighted.

10. The method as recited in Claim 9,
wherein the evaluation and weighting are carried out using a
video camera, a preferably satellite-supported navigational
system, a system for analyzing fixed destinations, or a system
for determining a collective yaw rate of objects (5,8) driving
ahead.

Abstract

A method for controlling the speed of a vehicle (1) is
proposed, where, in the vehicle (1) to be controlled, the yaw

5   rate or rotation rate is measured, in particular to determine
the curvature (k) of the vehicle's own travel trajectory, and
where, using a proximity sensor or position sensor (6), at
least one vehicle (5,8) traveling ahead or at least some other
object within a sensor's sensing range (7) is detected,

10   particularly with regard to an offset from the travel course
of the vehicle to be controlled. By delaying the travel-course
offset (yc) of a vehicle (5) driving ahead, determined in
preset measuring cycles, by a predefined time span (t_{hist}), and
by using the then instantaneous curvature (k) of the travel

15   trajectory, a historical travel-course offset (yc_{hist}) is
ascertained, one is able to simply and rapidly predict the
travel course of the vehicle (1) to be controlled.

(Figure 1)

20